# QUANTIFICATION PROTOCOL FOR EMISSION REDUCTIONS FROM DAIRY CATTLE

**Version 1.0**

**January 2010**

**Specified Gas Emitters Regulation**

Government of Alberta

Alberta

**Disclaimer:**

The information provided in this document is intended as guidance only and is subject to revisions as learnings and new information comes forward as part of a commitment to continuous improvement. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and the legislation for all purposes of interpreting and applying the law. In the event that there is a difference between this document and the *Specified Gas Emitters Regulation* or legislation, the *Specified Gas Emitters Regulation* or the legislation prevail.

All Quantification Protocols approved under the *Specified Gas Emitters Regulation* are subject to periodic review as deemed necessary by the Department, and will be re-examined at a minimum of every 5 years from the original publication date to ensure methodologies and science continue to reflect best-available knowledge and best practices. This 5-year review will not impact the credit duration stream of projects that have been initiated under previous versions of the protocol. Any updates to protocols occurring as a result of the 5-year and/or other reviews will apply at the end of the first credit duration period for applicable project extensions.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

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# 1.0 PROJECT AND METHODOLOGY SCOPE AND DESCRIPTION

## 1.1 Protocol Scope and Description

This quantification Protocol has been developed with the purpose of quantifying greenhouse gas (GHG) emissions and emission reductions from Dairy Farms in Canada. Greenhouse Gas emissions are to be normalized to unit of "greenhouse gas emissions per unit of fat corrected milk (FCM) produced".

The scope of the Protocol encompasses the animals, buildings, and land which constitute the biophysical system of a dairy farm. However, because of the complexity of the system, and because of on-going development of other greenhouse gas quantification protocols in Canada, some aspects of the animal/building/land system are simplified or excluded

**FIGURE 1.1** offers a typical process flow diagram for a typical project.

This protocol is intended to quantify emissions and emission reductions of carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) for dairy farms in Canada. The main sources of greenhouse gas emissions from dairy farms include $CH_4$ emissions from enteric fermentation and manure, $N_2O$ emissions from manure, and $CO_2$ and $N_2O$ emissions from feed production. Although the type of greenhouse gas emissions reduced under this protocol will be dependent on the specific project(s) undertaken, the majority of projects will result in emission reductions of $CO_2$, $CH_4$, and $N_2O$.

All projects are required to take place on Alberta dairy farms. For the purpose of this protocol, a "dairy farm" is described as any farm which produces milk for eventual retail sale. For this Protocol, a "dairy farm" may conduct other farming practices such as beef or veal farming, while maintaining its status as a "dairy farm" provided that it continues to produce milk for retail sale.

A variety of project scenarios may be undertaken at the farm-level to reduce greenhouse gas emissions – a detailed description of typical project scenarios is described in **TABLE 1.1**.

**Protocol Flexibility**

Other protocols relating to specific aspects of dairy farm operation are currently available or under development. This Protocol is designed to link and complement relevant protocols to provide additional flexibility and opportunity to mitigate greenhouse gas emissions and create greenhouse gas reduction credits.

This Protocol provides flexibility for the user by introducing Basic and Advanced approaches to greenhouse gas emission quantification for specific sources. The basic approach for

quantification will use accepted emission factors or default assessments of feed quality/greenhouse gas emissions, while the Advanced approach will require on-site measurement (with proper calibrations and quality assurance/quality control procedures, including attestation by the consulting nutritionist). Basic and Advanced approaches are not available in all quantifications; wherever flexibility is an option, the requirements and result of each approach will be stated.

Protocol participants using the Basic approach will use a discount factor to decrease the number of greenhouse gas reduction credits created. To be eligible for "Advanced approach" benefits, participants in the Protocol must follow the Advanced approach for all quantification calculations which offer such flexibility (no Basic approaches may be followed). The discount factor scheme is outlined in **TABLE 1.2**. **FIGURE 1.2** outlines a process flow diagram for a typical baseline configuration.

**TABLE 1.1** – Detailed Description of Typical Project Scenarios

| Potential Scenarios | Description |
|---|---|
| 1 | Annual milk productivity per cow is increased, thus reducing greenhouse gas emissions per unit of milk produced from all sources and sinks. |
| 2 | Diet is modified to reduce the proportion of gross energy converted to methane ($Y_M$) |
| 3 | Fewer heifers are retained as replacements to reduce emissions derived from replacement animals |
| 4 | Timing of manure spreading is modified to reduce methane emissions from storage unit |

**TABLE 1.2** - Discount Factors for Basic and Advanced Approaches

| Advanced Approaches Only Used in Dairy Protocol | Basic Approaches Used in Dairy Protocol | % of Greenhouse Gas Credits to be Received under this Protocol |
|---|---|---|
| YES | NO | 100 |
| NO | YES | 80 |

**FIGURE 1.1 -** Process Flow Diagram for Project Condition

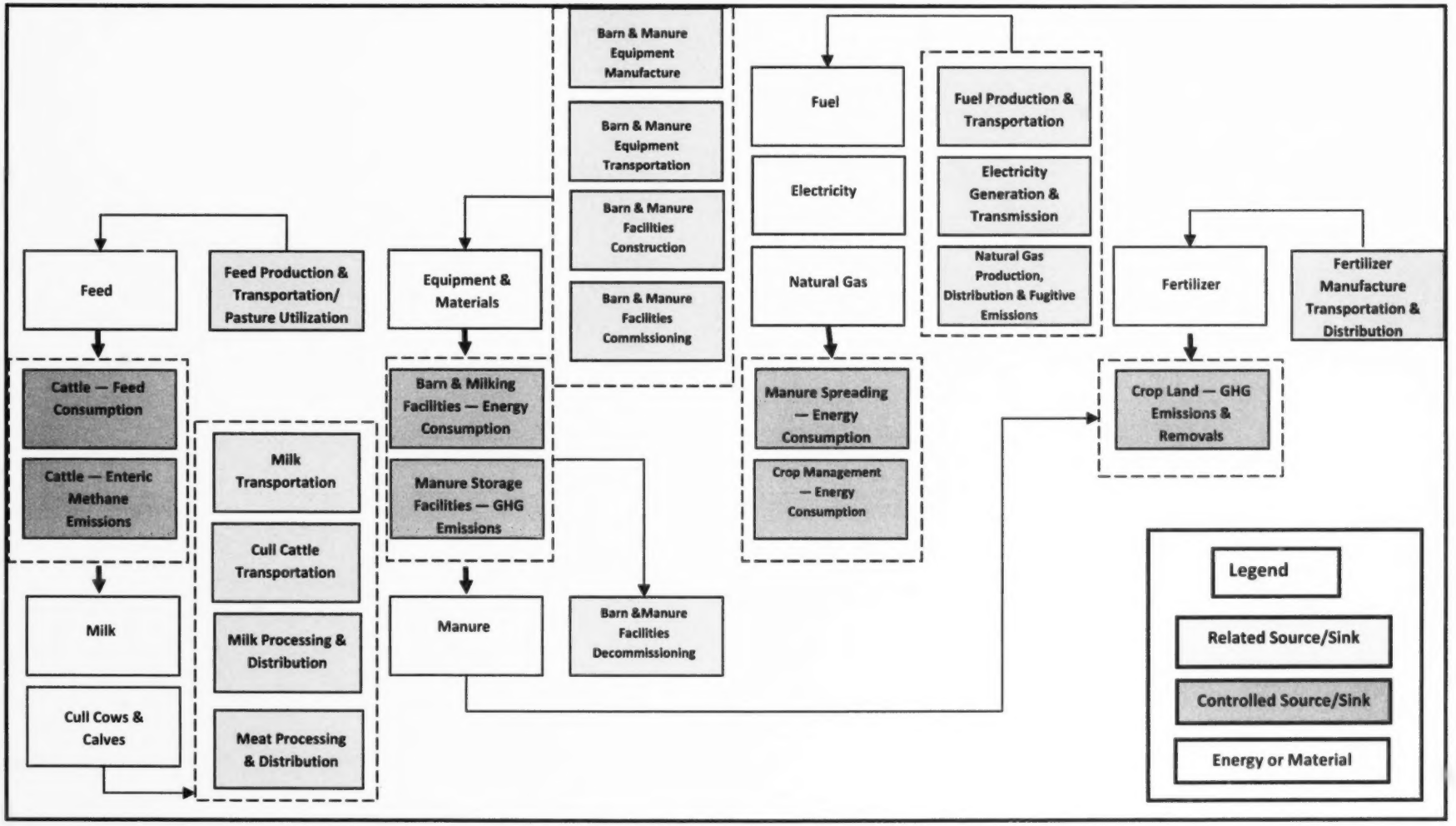
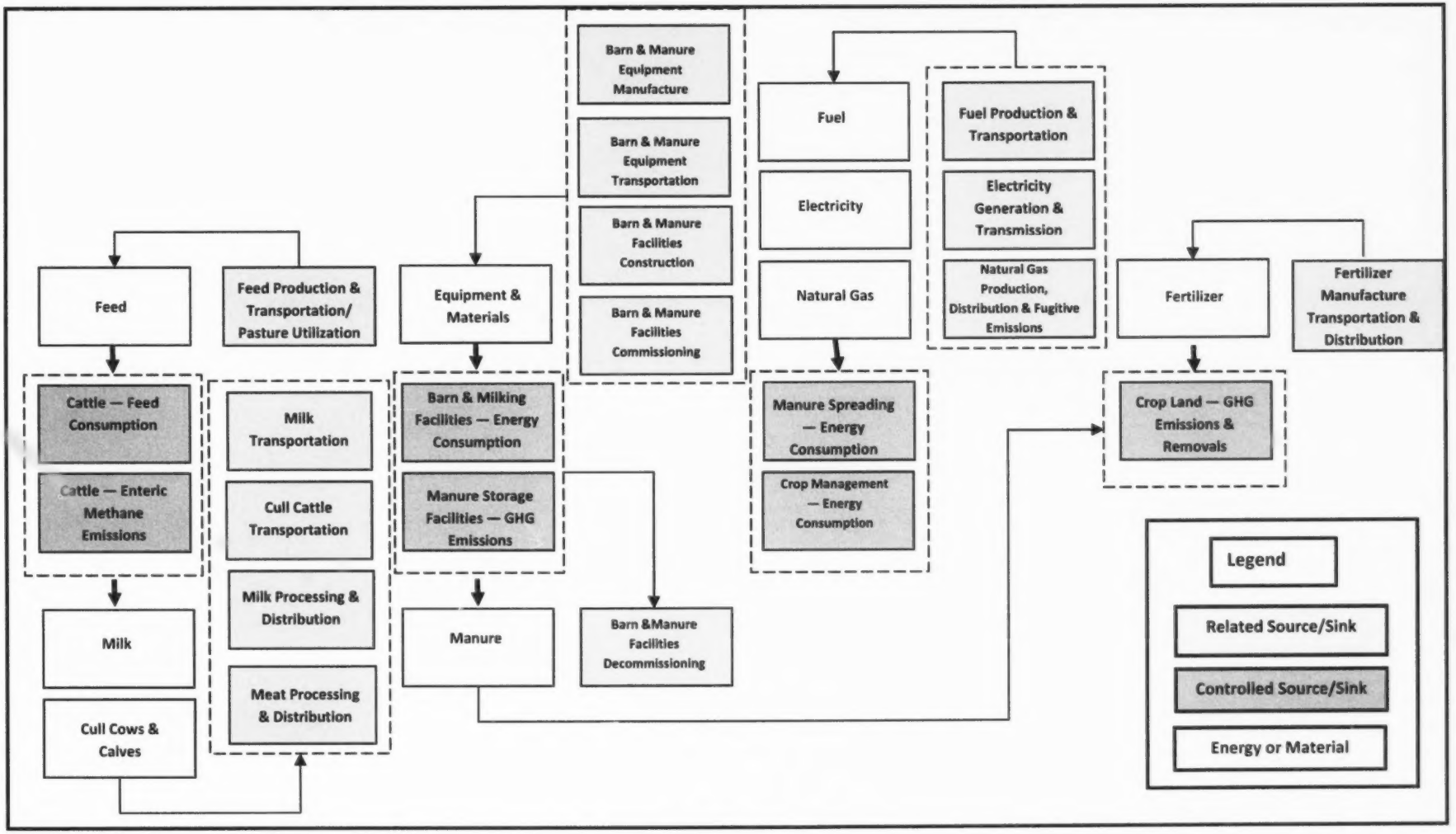


**FIGURE 1.2** - Process Flow Diagram for Baseline Condition



## 1.2 Glossary of New Terms

| | |
|---|---|
| **Acid Detergent Fibre (ADF)** | The fibrous, least-digestible portion of roughage. ADF consists of the highly indigestible parts of the forage, including lignin, cellulose, silica and insoluble forms of nitrogen. Roughages high in ADF are lower in digestible energy than roughages that contain low levels of ADF. As ADF levels increase, digestible energy levels decrease.† |
| **Attestation** | This formal document, with signature of the professional nutritionist, is required in some instances in the Protocol to serve as evidence concerning data quality or practice change. This dated and signed document will attest (1) to the accuracy of data regarding animal inventory, diet composition, feed quality, feed consumption, etc., or, (2) to the correctness of implementation of greenhouse gas reduction practices. |
| **Concentrates** | A broad classification of feedstuffs which are high in energy and low in crude fibre (<18 per cent Crude Fibre). This can include grains and protein supplements, but excludes feedstuffs like hay or silage or other roughage.† |
| **Dry Cows** | Cows that are not producing milk (not lactating). |
| **Dry Matter** | Total weight of feed minus the weight of water in the feed, expressed as a percentage. May also be referred to as: dry, dry basis, dry result, or moisture-free basis. You can convert from As-fed basis or dry matter basis by using the following formulas: DM basis = As-fed basis x (Dry Matter %/100) or As-fed basis = DM basis x (Dry Matter %/100).† |
| **Dry Matter Intake (DMI)** | All the nutrients contained in the dry portion of the feed consumed by animals.† |
| **Edible Oils** | Oils derived from plants that are composed primarily of triglycerides. Although many different parts of plants may yield oil, in commercial practice oil is extracted primarily |

| | |
|---|---|
| | from the seeds of oilseed plants. Whole seeds can be applied as a feed ingredient so long as the oil content is calculated on a dry matter basis to achieve the 4 to 6 per cent content in the diet. † |
| **Enteric Methane Emission** | Methane ($CH_4$) released by cattle (or other ruminants) as part of the normal digestive process. |
| **Fat Corrected Milk (FCM)** | Quantity of milk, normalized to a common energy basis. FCM is used in the scientific literature to mean 4 per cent fat corrected milk. The equation for calculating it is given as:<br>• kg FCM = 0.4 x kg milk + {(15 x % fat/100)} x kg milk<br>Source: Dairy Reference Manual (3rd Edition). Penn State University.<br>However, for this Protocol, the milk quantity is corrected to 3.7 per cent fat. And, the equation is:<br>• kg 3.7% FCM = (kg milk production * (3.7 / actual fat %). |
| **Forage** | High fibre feed, produced from grasses and legumes. Examples of forages include hay, pasture or silage. Forage is often referred to as roughages. |
| **Gestation** | The carrying of an embryo or fetus |
| **Gross Energy** | The total energy contained in feed; measured by calorimetry |
| **Hay** | Dried forage used for feed. |
| **Heifer** | A young, female cow that has not given birth to a calf. |
| **Ionophores** | Antimicrobial compounds fed to animals to improve feed efficiency. |
| **Lactation/Lactating** | Process of producing and/or secreting milk |
| **Liquid Manure** | Manure with water added to it during the collection, |

| | |
|---|---|
| | storage, or treatment process. |
| **Methane ($CH_4$)** | A greenhouse gas with a global warming potential (GWP) of 21. |
| **Neutral Detergent Fibre (NDF)** | Commonly called "cell walls." NDF give a close estimate of fibre constituents of feedstuffs as they measures cellulose, hemi-cellulose, lignin, silica, tannins and cutins. Neutral detergent fibre has been shown to be negatively correlated with dry matter intake. As the NDF in forages increases, animals will be able to consume less forage. NDF is used in formulas to predict the dry matter intake of cattle.† |
| **Nitrous Oxide ($N_2O$)** | A greenhouse gas with a GWP of 310. |
| **Nutritionist** | A qualified professional providing advice concerning the formulation of rations for dairy cows. To be considered a qualified nutritionist for the purpose of the Protocol, this advisor will demonstrate credentials from an accepted professional body. |
| **Pasture** | Land with vegetation used for grazing of cows and other livestock. |
| **Protein** | Complex compounds containing carbon, hydrogen, oxygen, nitrogen and usually sulphur - composed of one or more chains of amino acids. Proteins are essential in the diet of animals for growth, lactation and reproduction. In ruminants (for example, cattle), the rumen microbes break down about 80 per cent of the protein in the feed to ammonia, carbon dioxide, volatile fatty acids and other carbon compounds. The microbes then use the ammonia to synthesize their own body protein. As feed is passed through the rumen into the rest of the digestive tract, the micro-organisms containing about 65 per cent of the high quality protein are washed along too. The ruminant obtains most of its required protein by digesting these micro-organisms.† |
| **Quota** | The quantity of milk a dairy farmer is permitted to sell. |

| | |
|---|---|
| **Replacement Cattle** | Young cattle (calves, heifers, bulls) raised on a farm to replace milk cows removed from the herd. |
| **Silage** | High-moisture fodder that is compressed and fermented (used as feed). |
| **Solid Manure** | Manure that has not undergone any treatment process involving the addition of water. |
| **Total Mixed Ration (TMR)** | Consists of all the feed ingredients — concentrates, forage, minerals and vitamins — mixed together to form the ration allowance for the animal.† |

All definitions marked with the symbol † are from "Alberta Agriculture and Rural Development".

# 2.0 QUANTIFICATION DEVELOPMENT AND JUSTIFICATION

## 2.1 Identification of Sources and Sinks for the Project

Sources and sinks were identified for the project by reviewing the seed protocol document and relevant process flow diagram. This process confirmed that sources and sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided in **FIGURE 1.1**, the project sources and sinks were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the sources and sinks and their classification as controlled, related, or affected are provided in **TABLE 2.1**.

**Procedures used for the identification of relevant sources and sinks:**

- Aggregation or disaggregation of identified sources and sinks. The number of sources and sinks defined and the degree of detail presented is determined in large part by data availability and required level of accuracy.

- Review system of sources and sinks identified for the project by confirming that:
  - all relevant sources and sinks are identified;
  - each source and sink is classified appropriately as controlled & owned, related or affected;
  - all greenhouse gas inputs and outputs for each element are identified; and
  - that the sequence of sources and sinks for the system is correct.
  - repeat previous steps as necessary

- Identification of all sources and sinks physically *related* to the primary project activities, by tracing products, materials and energy inputs/outputs upstream to origins in natural resources and downstream along their life-cycles. (For example electricity production, fossil fuel production, etc)

- For each identified source and sink the parameters required to estimate or measure the greenhouse gases are determined including materials and energy inputs/outputs, and information on activities, products and services.

- Determination of the function[1] provided by the system of sources and sinks in order to assist in assessing equivalence of service between the project and the baseline scenario.

[1] The function is the products, goods and/or services provided by the sources and sinks identified for the project scenario.

**FIGURE 2.1** – Project Element Life Cycle Chart

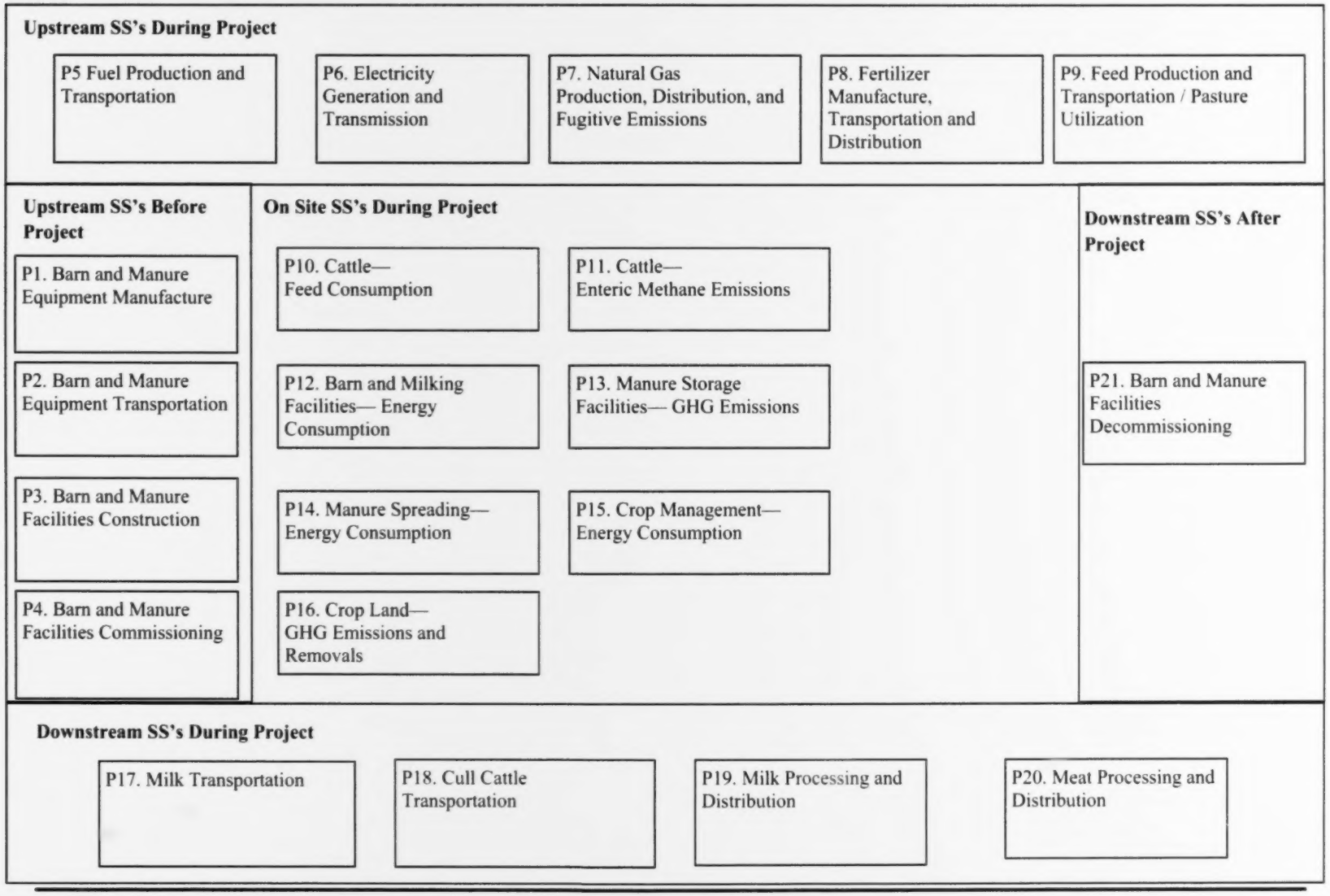

Upstream SS's During Project
P5 Fuel Production and Transportation
P6. Electricity Generation and Transmission
P7. Natural Gas Production, Distribution, and Fugitive Emissions
P8. Fertilizer Manufacture, Transportation and Distribution
P9. Feed Production and Transportation / Pasture Utilization
Upstream SS's Before Project
P1. Barn and Manure Equipment Manufacture
P2. Barn and Manure Equipment Transportation
P3. Barn and Manure Facilities Construction
P4. Barn and Manure Facilities Commissioning
On Site SS's During Project
P10. Cattle— Feed Consumption
P11. Cattle— Enteric Methane Emissions
P12. Barn and Milking Facilities— Energy Consumption
P13. Manure Storage Facilities— GHG Emissions
P14. Manure Spreading— Energy Consumption
P15. Crop Management— Energy Consumption
P16. Crop Land— GHG Emissions and Removals
Downstream SS's After Project
P21. Barn and Manure Facilities Decommissioning
Downstream SS's During Project
P17. Milk Transportation
P18. Cull Cattle Transportation
P19. Milk Processing and Distribution
P20. Meat Processing and Distribution

**TABLE 2.1** –Project Sources and Sinks

| Sources/Sinks | Description | Controlled, Affected, Related |
|---|---|---|
| ***Upstream Sources and Sinks Before Project*** | | |
| P1. Barn & Manure Equipment Manufacture | All activities (inputs of materials and energy) required to manufacture equipment used for barn and manure systems. | Related |
| P2. Barn & Manure Equipment Transportation | All activities (inputs of materials and energy) required to transport equipment used for barn and manure systems from the manufacturing location to the project location (farm). | Related |
| P3. Barn & Manure Facilities Construction | All activities (inputs of materials and energy) involved in the construction of the barn and manure systems. | Related |
| P4. Barn & Manure Facilities Commissioning | All activities (inputs of materials and energy) involved in the commissioning of the barn and manure systems. | Related |
| ***Upstream Sources and Sinks During Project*** | | |
| P5. Fuel Production and Transportation | All activities (inputs of materials and energy) involved in the production and transportation of diesel fuel. | Related |
| P6. Electricity Generation and Transmission | All activities (inputs of materials and energy) involved in the generation of electricity. | Related |
| P7. Natural Gas Production, Distribution, and Fugitive Emissions | All activities (inputs of materials and energy) involved in the discovery and production of natural gas. Because natural gas is a greenhouse gas (primarily composed of $CH_4$), fugitive emissions during production are included in this element. | Related |
| P8. Fertilizer Manufacture, Transportation and Distribution | All activities (inputs of materials and energy) involved in production, transportation, and distribution of fertilizer. | Related |
| P9. Feed Production and Transportation / Pasture Utilization | All activities (inputs of materials and energy) involved in the production (crop growing & harvesting) and transportation of feed. | Related |
| ***Onsite Sources and Sinks During Project*** | | |
| P10. Cattle – Feed Consumption | All activities (inputs of materials and energy) involved in the use of feed. Feed or dairy farm is both raised on farm and purchased from off-farm sources. | Controlled |
| P11. Cattle – Enteric Methane Emissions | Emissions produced as a result of digestion of feed by cattle, released through exhalation. Also refers to practices to manage feed composition to control enteric emissions. | Controlled |
| P12. Barn & Milking Facilities – Energy Consumption | Fuel and electricity used to operate the barn and milking facilities, including on-farm handling of feed and bedding. | Controlled |
| P13. Manure Storage Facilities – greenhouse Gas Emissions | Fuel and electricity used to operate the manure storage facilities. Also refers to practices to | Controlled |

| | | |
|---|---|---|
| | reduce emissions of greenhouse gases from the stored manure. | |
| P14. Manure Spreading – Energy Consumption | All activities (inputs of materials and energy) involved in the spreading of manure, with the exception of fuel use. Also refers to practices to reduce greenhouse gases from the spread manure. | Controlled |
| P15. Crop Management – Energy Consumption | Fuel used to maintain till soil, and to raise and harvest crops. | Controlled |
| P16. Crop Land – Greenhouse Gas Emissions & Removals | Greenhouse Gas emissions and removals associated with typical land use, including emissions from fertilizer and decomposing crop residues. | Controlled |
| ***Downstream Sources and Sinks During Project*** | | |
| P17. Milk Transportation | All activities (inputs of materials and energy) involved in the transport of milk that is an output of the project farm. | Related |
| P18. Cull Cattle Transportation | All activities (inputs of materials and energy) involved in the transport of cull cattle from the project farm. | Related |
| P19. Milk Processing & Distribution | All activities (inputs of materials and energy) involved in processing and distributing milk from the project farm for retail sale. | Related |
| P20. Meat Processing & Distribution | All activities (inputs of materials and energy) involved in the processing and distribution of meat from the project farm for retail sale. | Related |
| ***Downstream Sources and Sinks After Project*** | | |
| P21. Barn & Manure Facilities Decommissioning | All activities (inputs of materials and energy) required to shut down the barn(s) and manure storage facility. | Related |

## 2.2 Identification of Baseline

The baseline scenario is the most appropriate and best estimate of greenhouse gas emissions and removals that would have occurred in the absence of any project(s). With respect to developing the baseline scenario for the Protocol and Calculator, two sets of circumstances must be considered to determine a baseline scenario. First, dairy farms across Canada can vary widely in their greenhouse gas emissions per kg of milk produced. Second, according to Canada Census data, the number of dairy cows and dairy farms steadily is declining, but total milk production continues to increase to meet the demand of increasing population. These same data, however, also point out that the rate of decline in greenhouse gas emissions per unit milk production has slowed such that further decrease in emissions will require incremental practice change.

The approach to quantifying the baseline will be primarily a Project-Specific Historic Benchmarks. This approach requires individual farms to calculate a baseline for each farm in the project for the 3-year period prior to project registration. Thus, each participating farm will use its own data (animal inventory, feed quality, feed quantity, milk production, manure spreading) to calculate baseline emissions per unit of milk on a 3.7 per cent fat corrected basis. The method is described in Section 2.5 to calculate greenhouse gas emissions per unit milk, with data needed outlined in **TABLE 2.5**.

**Baseline Scenario Adjustments**

The baseline scenario identified for the projects eligible under this quantification protocol may require adjustments to ensure consistency with the project. These adjustments are usually performed when the energy savings are quantified. In many cases, the quantification and claims of greenhouse gas emission reductions will occur on a yearly basis, therefore these adjustments will need to be performed according to that same schedule.

## 2.3 Identification of Sources and Sinks for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project sources and sinks were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the sources and sinks and their classification as either 'controlled', 'related', or 'affected' is provided in **TABLE 2.2**.

**Historical Benchmark and Performance Standard**

All sources and sinks relevant to the baseline scenario selected must be identified. In addition to on-site sources and sinks, sources and sinks upstream and downstream of the facility must also be identified.

**FIGURE 2.2** – Baseline Element Life Cycle Chart

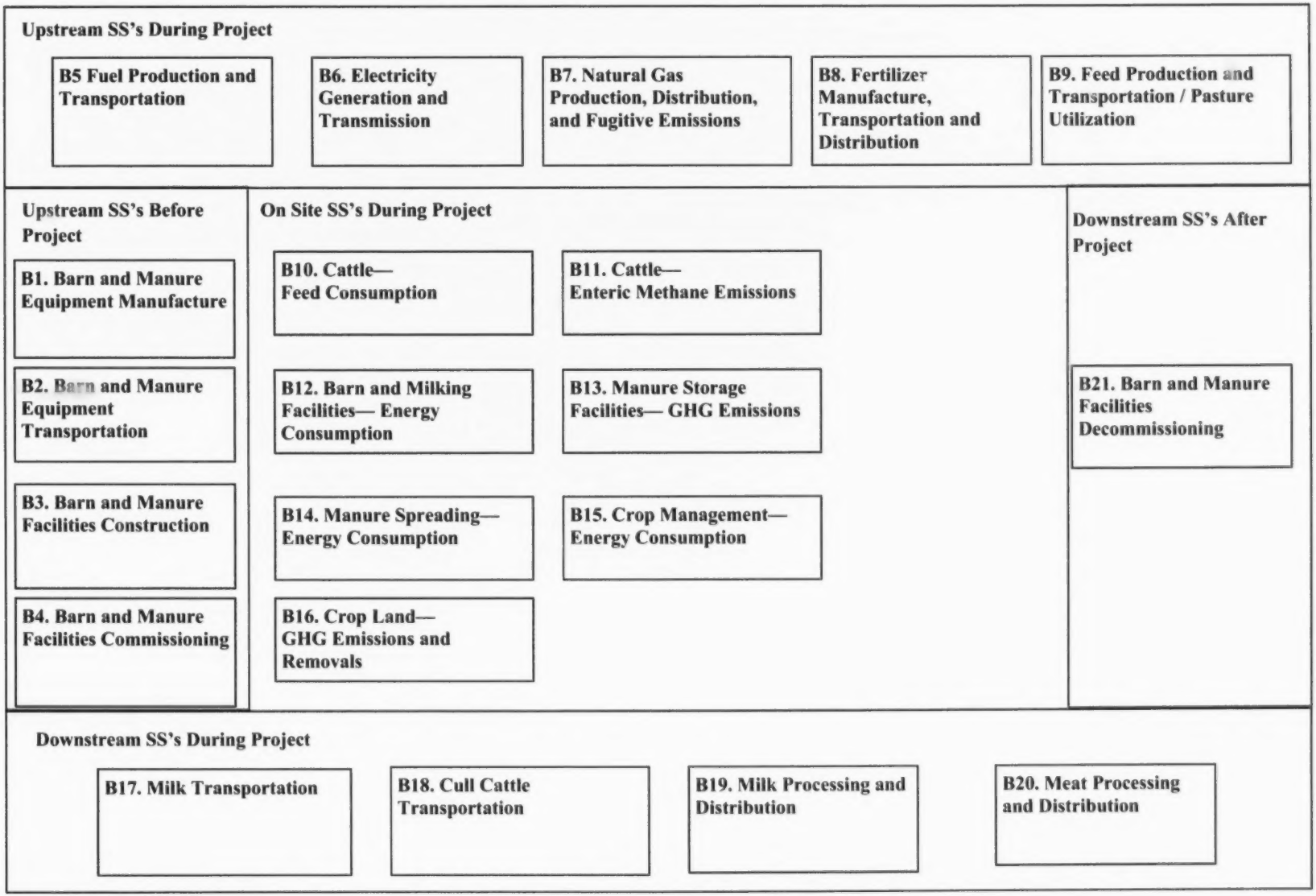

Upstream SS's During Project
B5 Fuel Production and Transportation
B6. Electricity Generation and Transmission
B7. Natural Gas Production, Distribution, and Fugitive Emissions
B8. Fertilizer Manufacture, Transportation and Distribution
B9. Feed Production and Transportation / Pasture Utilization
Upstream SS's Before Project
B1. Barn and Manure Equipment Manufacture
B2. Barn and Manure Equipment Transportation
B3. Barn and Manure Facilities Construction
B4. Barn and Manure Facilities Commissioning
On Site SS's During Project
B10. Cattle— Feed Consumption
B11. Cattle— Enteric Methane Emissions
B12. Barn and Milking Facilities— Energy Consumption
B13. Manure Storage Facilities— GHG Emissions
B14. Manure Spreading— Energy Consumption
B15. Crop Management— Energy Consumption
B16. Crop Land— GHG Emissions and Removals
Downstream SS's After Project
B21. Barn and Manure Facilities Decommissioning
Downstream SS's During Project
B17. Milk Transportation
B18. Cull Cattle Transportation
B19. Milk Processing and Distribution
B20. Meat Processing and Distribution

**TABLE 2.2** – Baseline Sources and Sinks

| Sources/Sinks | Description | Controlled, Affected, Related |
|---|---|---|
| ***Upstream Sources and Sinks Before Project*** | | |
| B1. Barn & Manure Equipment Manufacture | All activities (inputs of materials and energy) required to manufacture equipment used for barn and manure systems. | Related |
| B2. Barn & Manure Equipment Transportation | All activities (inputs of materials and energy) required to transport equipment used for barn and manure systems from the manufacturing location to the project location (farm). | Related |
| B3. Barn & Manure Facilities Construction | All activities (inputs of materials and energy) involved in the construction of the barn and manure systems. | Related |
| B4. Barn & Manure Facilities Commissioning | All activities (inputs of materials and energy) involved in the commissioning of the barn and manure systems. | Related |
| ***Upstream Sources and Sinks During Project*** | | |
| B5. Fuel Production and Transportation | All activities (inputs of materials and energy) involved in the production and transportation of diesel fuel. | Related |
| B6. Electricity Generation and Transmission | All activities (inputs of materials and energy) involved in the generation of electricity. | Related |
| B7. Natural Gas Production, Distribution, and Fugitive Emissions | All activities (inputs of materials and energy) involved in the discovery and production of natural gas. Because natural gas is a greenhouse gas (primarily composed of $CH_4$), fugitive emissions during production are included in this element. | Related |
| B8. Fertilizer Manufacture, Transportation and Distribution | All activities (inputs of materials and energy) involved in production, transportation, and distribution of fertilizer. | Related |
| B9. Feed Production and Transportation / Pasture Utilization | All activities (inputs of materials and energy) involved in the production (crop growing & harvesting) and transportation of feed. | Related |
| ***Onsite Sources and Sinks During Project*** | | |
| B10. Cattle – Feed Consumption | All activities (inputs of materials and energy) involved in the use of feed. Feed or dairy farm is both raised on farm and purchased from off-farm sources. | Controlled |
| B11. Cattle – Enteric Methane Emissions | Emissions produced as a result of digestion of feed by cattle, released through exhalation. Also refers to practices to manage feed composition to control enteric emissions. | Controlled |
| B12. Barn & Milking Facilities – Energy Consumption | Fuel and electricity used to operate the barn and milking facilities, including on-farm handling of feed and bedding. | Controlled |
| B13. Manure Storage Facilities – Greenhouse Gas Emissions | Fuel and electricity used to operate the manure storage facilities. Also refers to practices to reduce emissions of greenhouse gases from the stored manure. | Controlled |
| B14. Manure Spreading – Energy | All activities (inputs of materials and energy) | Controlled |

| | | |
|---|---|---|
| Consumption | involved in the spreading of manure, with the exception of fuel use. Also refers to practices to reduce greenhouse gases from the spread manure. | |
| B15. Crop Management – Energy Consumption | Fuel used to maintain till soil, and to raise and harvest crops. | Controlled |
| B16. Crop Land – Greenhouse Gas Emissions & Removals | Greenhouse Gas emissions and removals associated with typical land use, including emissions from fertilizer and decomposing crop residues. | Controlled |
| ***Downstream Sources and Sinks During Project*** | | |
| B17. Milk Transportation | All activities (inputs of materials and energy) involved in the transport of milk that is an output of the project farm. | Related |
| B18. Cull Cattle Transportation | All activities (inputs of materials and energy) involved in the transport of cull cattle from the project farm. | Related |
| B19. Milk Processing & Distribution | All activities (inputs of materials and energy) involved in processing and distributing milk from the project farm for retail sale. | Related |
| B20. Meat Processing & Distribution | All activities (inputs of materials and energy) involved in the processing and distribution of meat from the project farm for retail sale. | Related |
| ***Downstream Sources and Sinks After Project*** | | |
| B21. Barn & Manure Facilities Decommissioning | All activities (inputs of materials and energy) required to shut down the barn(s) and manure storage facility. | Related |

## 2.4 Selection of Relevant Project and Baseline Sources and Sinks

Each of the sources and sinks from the project and baseline condition were compared and evaluated as to their relevancy and to determine if it is necessary to quantify the greenhouse gas emissions by direct monitoring or estimation. This procedure was adapted form Canada's Offset System for Greenhouse Gases – Guide for Protocol Developers (August 2008-Draft version). The justification for the exclusion or conditions on which sources and sinks may be excluded is provided in **TABLE 2.3**. All other sources and sinks listed previously are included.

**TABLE 2.3** – Comparison of Sources and Sinks

| Identified Sources and Sinks | Baseline (C, R, A) | Project (C, R, A) | Include or Exclude from Quantification | Justification for Exclusion |
|---|---|---|---|---|
| ***Upstream Sources and Sinks*** | | | | |
| B1/P1. Barn & Manure Equipment Manufacture | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B2/P2. Barn & Manure Equipment Transportation | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B3/P3. Barn & Manure Facilities Construction | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B4/P4. Barn & Manure Facilities Commissioning | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B5/P5. Fuel Production and Transportation | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B6/P6. Electricity Generation and Transmission | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B7/P7. Natural Gas Production, Distribution, and Fugitive Emissions | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B8/P8. Fertilizer Manufacture, Transportation and Distribution | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B9/P9. Feed Production and Transportation / Pasture Utilization | Related | Related | Include | This element comprises some of the practices for greenhouse gas reduction included in the protocol. To accommodate on- |

| | | | | |
|---|---|---|---|---|
| | | | | and off-farm sources of feed, standardized assessment of 'embedded emissions' are used to account for greenhouse gas intensity of feedstuffs. |
| ***Onsite Sources and Sinks*** | | | | |
| B10/P10. Cattle – Feed Consumption | Controlled | Controlled | Include | This element comprises some of the practices for greenhouse gas reduction included in the protocol. |
| B11/P11. Cattle – Enteric Methane Emissions | Controlled | Controlled | Include | This element comprises some of the practices for greenhouse gas reduction included in the protocol. |
| B12/P12. Barn & Milking Facilities – Energy Consumption | Controlled | Controlled | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Exclusion of this SS represents conservativeness concerning quantification of reductions. Also, this Protocol encourages participants to enrol in an Energy Efficiency Protocol to capture potential reductions from decreased use of energy. |
| B13/P13. Manure Storage Facilities – Greenhouse Gas Emissions | Controlled | Controlled | Include | This element comprises some of the practices for greenhouse gas reduction included in the protocol. |
| B14/P14. Manure Spreading – Energy Consumption | Controlled | Controlled | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Exclusion of this SS represents conservativeness concerning quantification of reductions. |
| B15/P15. Crop Management – Energy Consumption | Controlled | Controlled | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Exclusion of this SS represents conservativeness concerning quantification of reductions. |
| B16/P16. Crop Land – Greenhouse Gas Emissions & Removals | Controlled | Controlled | Include | These emissions and removals are addressed in the standard greenhouse gas intensity of feedstuffs. |

| ***Downstream Sources and Sinks*** | | | | |
|---|---|---|---|---|
| B17/P17. Milk Transportation | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B18/P18. Cull Cattle Transportation | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B19/P19. Milk Processing & Distribution | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B20/P20. Meat Processing & Distribution | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |
| B21/P21. Barn & Manure Facilities Decommissioning | Related | Related | Exclude | The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. |

## 2.5 Quantification of Reductions, Removals and Reversals of Relevant Sources and Sinks

### 2.5.1 Quantification Approaches

Quantification of the reductions, removals, and reversals of relevant sources and sinks for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.5**. These calculation methodologies serve to complete the following equations for calculating the emission reductions from the comparison of the baseline and project conditions.
greenhouse gas emission reductions are calculated using Equation 1, below.

**Greenhouse Gas Emission Reductions = (Baseline Emissions – Project Emissions) * Milk[1]**

Where:

> **Baseline Greenhouse Gas Emissions** and **Project Greenhouse Gas Emissions** are the greenhouse gas emissions quantified per kg fat corrected milk for the baseline and project scenarios, respectively; and
> **Milk**[2] is the total milk production in the Project, expressed as Fat Corrected Milk (FCM).

Greenhouse Gas emissions for both the project and baseline scenario are calculated using Equation 2. Various multiplication factors are used for the quantification of each source and sink and are described in their respective sections of this protocol.

**Greenhouse Gas Emissions = Activity Level × Multiplication Factors [2]**

Where:

> **Activity Level** represents the "quantity" of a particular input, dependant on sources and sinks
>
> **Multiplication Factors** represents the various factors used to convert the activity level to an appropriate unit of greenhouse gases

Activity levels will be either measured or estimated, depending on the source and/or sink while multiplication factors will be acquired from current published documentation.

**Application of Discount Factor**

Once all greenhouse gas emission reductions have been properly calculated, the appropriate discount factor must be applied. The discount factor used to determine eligible greenhouse gas

[2] The total milk production data will be based on the data provided thorough the farm participation in a milk reporting program.

reductions depends on the quantification approach, Basic or Advanced[3,4], used to determine greenhouse gas emissions and reductions.

The discount factor is to be applied by multiplying the total greenhouse gas emissions from all sources and sinks by the discount factor, yielding total eligible greenhouse gas emission reductions.

**Manure Storage Facilities – Greenhouse Gas Emissions**

Basic Approach — $CH_4$ Emissions - Method 1: Annually

Methane emissions from manure storage are calculated using Equation 3.

$$E_{SSR13,CH4} = \sum_{S,G} VS_G * N_G * 365 * 0.24 * 0.67 * MCF_S * MS_{S,G} * 21 / 1000 \quad [3]$$

Where:

$E_{SSR13,CH4}$ = Methane emissions from manure management, tonnes $CO_{2e}$ $yr^{-1}$
**S** = Manure management system (liquid, solid or pasture)
**G** = Animal group
$VS_G$ = Daily volatile solids excreted by a specific animal group, kg DM $head^{-1}$ $day^{-1}$
$N_G$ = Number of animals in a specific animal group
**365** = Number of days per year
**0.24** = Maximum methane-producing capacity from dairy manure ($m^3$ $CH_4$ $kg^{-1}$ of VS excreted)
**0.67** = Coefficient to convert $m^3$ to kg for methane, kg $CH_4$ $m^{-3}$ $CH_4$
$MCF_S$ = Methane conversion factor: per cent of VS converted to methane for the defined manure management system
$MS_{S,G}$ = Fraction of animal group G's manure handled by the defined manure management system
**21** = Global warming potential of methane
**1000** = kg per tonne

The "daily volatile solids excreted by a specific animal group", $VS_G$, in Equation 3 is calculated using Equation 4, below.

$$VS = (GE * (1-DE/100) + 0.04 * GE) * 0.92 / 18.45 \quad [4]$$

Where:

**VS** = Daily volatile solids excreted per day on a dry matter basis, kg $head^{-1}$ $day^{-1}$

[3] In instances where the calculations in the Advanced approach are based on data concerning the quantity and quality of feed used on the farm, these data will be attested by the nutritionist retained by the farm.
[4] Note: The Basic and Advanced quantification approaches can **not** be used together as a "mixed" approach

**GE** = Gross energy intake, MJ head$^{-1}$ day$^{-1}$
**DE** = Digestible energy expressed as a percentage of gross energy
**0.04** = Urinary energy excretion expressed as a fraction of GE
**0.92** = Fraction ash-free content of manure
**18.45** = Average energy content of dry matter (MJ kg$^{-1}$)

The "methane conversion factor", $MCF_S$, in Equation 3 is listed by manure system and region in **TABLE 2.4.1** below.

**TABLE 2.4.1 - Methane Conversion Factors ($MCF_S$)**

| Manure System | Region | MCF (%)† |
|---|---|---|
| Solid | All regions | 1.0 |
| Liquid | BC | 25.8 |
| | Prairies | 28.3 |
| | ON | 30.1 |
| | PQ | 28.4 |
| | Atlantic | 29.4 |
| Pasture | All regions | 1.0 |

†Based on Marinier et al. 2004 and Vergé et al. 2007

Advanced Approach — $CH_4$ Emissions - Method 2: Monthly

To account for the influence of temperature and timing of manure removal on methane emissions from liquid manure storage units, methane emissions can also be calculated monthly, following Equation 5.

$$E_{SSR13,CH4,L} = \sum_{m} (VS_{avail,m} * f_m) * 0.24 * 0.67 * 21 * 1000 \quad [5]$$

Where:

$E_{SSR13,CH4,,L}$ = Methane emissions from a liquid manure storage unit, kilogram $CO_{2e}$ yr$^{-1}$
**m** = Month (for a one year period)
$VS_{prod,m}$ = Volatile solids added to manure storage unit during month (tonnes) (calculated for all animal groups contributing to unit)
$VS_{avail,m-1}$ = Volatile solids in the storage unit at the end of the previous month available to be consumed by decomposer microorganisms
$f_m$ = Fraction of available volatile solids consumed during month, Vant Hoff Arrhenius factor.
$VS_{avail,m-1}$, above, is calculated using Equation 6;

$$VS_{avail,m} = VS_{avail,\,m-1} + VS_{prod,m} - VS_{consumed,m-1} - VS_{stabilized,m} - VS_{removed} \quad [6]$$

Where:

**$VS_{avail,m}$** = Volatile solids available to be decomposed at end of current month (tonnes)
**$VS_{avail,\,m-1}$** = Volatile solids available to be decomposed at end of previous month (tonnes)
**$VS_{prod,m}$** = Volatile solids added to manure storage unit during month (tonnes)
**$VS_{consumed\,m}$** = Volatile solids consumed during month (tonnes)
$= VS_{avail,m} * f_m$
**$VS_{stabilized}$** = Volatile solids stabilized into non-available forms (tonnes)
$= VS_{prod,m} * 0.55$
**$VS_{removed}$** = Volatile solids removed from manure storage during month (tonnes)

The "fraction of available volatile solids consumed during month", f, in Equation 5 is calculated using Equation 7, below.

$$f = \exp[E(T_2-T_1)/(RT_1T_2)] \quad [7]$$

Where:

**E** = activation energy constant (63,515 J $mol^{-1}$)
**$T_2$** = average monthly temperature ($^oK = {}^oC + 273$, $T_2 \geq 5\ {}^oC$)
**$T_1$** = 303 $^oK$
**R** = ideal gas constant (8.317 J $K^{-1}$ $mol^{-1}$)

**$N_2O$ Emissions from Manure Storage**

Nitrous oxide emissions from manure storage can be calculated using Equation 8. The assessment of the protein content of the diet and the intake of feed is provided by the nutritionist formulating the rations for the dairy cows, and this professional will attest to the accuracy of the monitoring procedures used.

$$E_{SSR13,N2O} = \sum_G (FeedN_G - MilkN_G - LWgainN_G) * 365 * N_G * E_{N2O,G} * 310 / 1000 \quad [8]$$

Where:

**$E_{SSR13,N2O}$** = $N_2O$ emissions from manure storage, tonnes $CO_{2e}$ $yr^{-1}$
**G** = Animal group
**$FeedN_G$** = Feed N intake for a specific animal group, kg N $head^{-1}$ $day^{-1}$
$= DMI * CP/100 * 0.16$

Where:

**DMI** = daily dry matter intake, kg head $day^{-1}$
**CP** = crude protein content of diet, per cent of DMI
**0.16** = fraction N in feed protein

**$MilkN_G$** = N retained in milk N for a specific animal group, kg N $head^{-1}$ $day^{-1}$
= Milk * Milk protein/100 * 0.157

Where:

**Milk** = daily milk production, kg head $day^{-1}$
**Milk protein** = protein content of milk, per cent on weight basis
**0.157** = fraction N in milk protein

**$LWgainN_G$** = N retained in live weight gain for a specific animal group, kg N $head^{-1}$ $day^{-1}$
= LWgain * 0.027

Where:

**LWgain** = daily live weight gain, kg head $day^{-1}$
**0.027** = fraction N in live weight gain

**365** = Number of days per year
**$N_G$** = Number of animals in a specific animal group
**$E_{N2O,G}$** = $N_2O$ emitted per kg of N excreted for a specific animal group, g $N_2O$ $kg^{-1}$ excreted N
= $F_{G,S}$ * $E_{N2O,S}$

Where:

**$F_{G,S}$** = Fraction of excreted N handled by manure management system for a specific animal group
**$E_{N2O,S}$** = $N_2O$ emitted per kg of N excreted in a specific manure management system (**TABLE 2.4.2**), g $N_2O$ $kg^{-1}$ excreted N

**310** = Global warming potential of $N_2O$
**1000** = kg per tone

**TABLE 2.4.2 - Direct and Indirect $N_2O$ Losses from Manure Storage Units for Different Manure Management Systems**

| Variable | Solid | Liquid | Pasture |
|---|---|---|---|
| Direct $N_2O$ losses, g N $kg^{-1}$ excreted N | 7.9 | 7.9‡ | 0 |
| Indirect $N_2O$ losses†, g N $kg^{-1}$ excreted N | 4.7 | 6.3 | 0 |
| $N_2O$ losses, g N $kg^{-1}$ excreted N | 12.6 | 14.1 | 0 |

†Assumed no N losses due to leaching
‡Assumed liquid storage units had natural crust covers

**Cattle – Enteric Methane Emissions**

Methane emissions from enteric fermentation can be calculated using Equation 9, below.

$$E_{SSR11} = \sum_{G} GE_G * (Y_{mG} / 100) * N_G * 365 / 55.65 * 21 / 1000 \qquad [9]$$

Where:

$E_{SSR11}$ = Methane emissions from enteric fermentation, tonnes $CO_2e\ yr^{-1}$
**G** = Animal group
$GE_G$ = Gross energy intake for a specific animal group (based on measured dry matter intake, MJ $head^{-1}$ $day^{-1}$
$Y_{MG}$ = Per cent of gross energy in feed converted to methane for a specific animal group
$N_G$ = Number of animals in a specific animal group
**365** = Number of days per year
**55.65** = Energy content of methane, MJ per kg methane
**21** = Global warming potential of methane
**1000** = kg per tonne

Dairy animals are generally grouped into milking cows (one to three groups), dry cows and replacement heifers (grouped by age). Male animals are excluded from calculations because adult bulls are rarely kept and bull calves are generally sold at a young age.

Replacement heifers are handled as one group, starting after weaning (assumed at end of two months) and extending until first calving (input variable). Weight gain is assumed to be constant over the growth period. Greenhouse Gas emissions are calculated for each month, based on calculated weights. Heifer ages are assumed to be distributed uniformly over the growth period. Pasture use and manure handling systems can be set differently for older heifers and younger heifers.

The $Y_M$ value is defined as the percentage of gross energy intake by the dairy cow that is converted to methane in the rumen. The Intergovernmental Panel on Climate Change (IPCC) (2006) uses $Y_M$ of 6.5 (± 1) per cent for ruminants, including dairy cows. In other words, 6.5 per cent of the gross energy consumed is converted in the rumen to methane energy. The associated uncertainty estimation of ± 1 per cent reflects the fact that diets can alter the proportion of feed energy emitted as enteric methane.

**Basic Approach**

"Gross energy intake", $GE_G$, in Equation 9 may be estimated using the energy required for a representative animal in each group using the approach outlined by IPCC (2006) (**TABLE 2.4.3**). The equations pertinent to enteric emissions from dairy cows are fully described in Chapter 10: Emissions from Livestock and Manure Management, of Volume 4: Agriculture, Forestry, and other Land Use, of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC equation number is listed in bold text in parentheses.

**TABLE 2.4.3 - Calculations of Net Energy Requirements using the IPCC Equations.**

| |
|---|
| $NE_m = Cf_i * LW^{0.75}$ **(10.3)**<br><br>Where:<br>$NE_m$ = Net energy for maintenance, MJ $head^{-1}$ $day^{-1}$<br>$Cf_i$ = Maintenance energy coefficient, MJ $day^{-1}$ $kg^{-1}$<br>(0.386 for cows in lactation, 0.322 for heifers and dry cows)<br>LW = Average liveweight (kg) |
| $NE_a = 0.17 * F_{pstr} * NE_m$ **(10.4)**<br><br>Where:<br>$NE_a$ = Net energy for activity, MJ $head^{-1}$ $day^{-1}$<br>0.17 = Coefficient for animals on pasture with sufficient forage for modest energy expense of feed acquisition<br>$F_{pstr}$ = Fraction of time spent on pasture |
| $NE_g = 22.02 * (BW/0.8/MW)^{0.75} * WG^{1.097}$ **(10.6)**<br><br>Where:<br>$NE_g$ = Net energy for growth, MJ $head^{-1}$ $day^{-1}$<br>BW = Average live body weight for animals in group, kg<br>MW = Mature live body weight of an adult cow, kg<br>WG = Average daily weight gain, kg $day^{-1}$ |
| $NE_l$ = Milk * (1.47 + 0.40 * Fat) **(10.8)**<br><br>Where:<br>$NE_l$ = Net energy for lactation, MJ $head^{-1}$ $day^{-1}$<br>Milk = Amount of milk produced, kg $head^{-1}$ $day^{-1}$<br>Fat = Fat content of milk, % by weight |
| $NE_p = 0.1 * F_{preg} * NE_m$ **(10.13)**<br><br>Where:<br>NEp = Net energy for pregnancy, MJ $head^{-1}$ $day^{-1}$<br>$F_{preg}$ = Fraction of animal group that are pregnant |
| $REM = 1.123 - 0.004092*DE + 0.00001126*DE^2 - 25.4/DE$ **(10.14)**<br><br>Where:<br>REM = Ratio of net energy available for maintenance to digestible energy consumed<br>DE = Digestible energy expressed as a percentage of gross energy |
| $REG = 1.164 - 0.005160*DE + 0.00001308*DE^2 - 37.4/DE$ **(10.15)**<br><br>Where:<br>REM = Ratio of net energy available for growth to digestible energy consumed<br>DE = Digestible energy expressed as a percentage of gross energy |
| $GE = [(NE_m + NE_a + NE_l + NE_p)/REM + NE_g/REG]/(DE/100)$ **(10.16)**<br><br>Where:<br>GE = Gross energy, MJ $head^{-1}$ $day^{-1}$ |

### Advanced Approach

Methane emissions from enteric fermentation may also be calculated more accurately by measuring the dry matter intake, DMI, on a daily basis using Equation 10.

$$GE_G = DMI/18.45 \qquad [10]$$

Where:

**DMI** = Dry matter intake, kg head$^{-1}$ day$^{-1}$
**18.45** = Average energy content of dry matter (MJ kg$^{-1}$)

The DMI value will be determined as the sum of all ration ingredients, but monitoring of individual ration ingredients is needed in the Advanced approach to determine the $Y_M$ value.

The default $Y_M$ value of IPCC was refined by Karen Beauchemin and Alan Fredeen to account for changes in ration formulation practices - to modify the proportion of gross energy converted to enteric $CH_4$ (**TABLE 2.4.4**). Thus, the Advanced approach of the Dairy Protocol allows farmers to modify diets to manipulate $Y_M$ within the range of variability of the IPPC default value. The assessment of the quality of forages is provided by the nutritionist formulating the rations for the dairy cows, and this professional must attest to the accuracy of the monitoring procedures used. This protocol will use the following rules for the $Y_M$ for dairy cows:

**TABLE 2.4.4 - Estimates of the Percentage of Gross Energy Converted to Methane ($Y_M$) for Various Diets**

| **Diet Description** | **Concentrate kg/ kg milk ( as is basis)** | **$Y_M$ (% of GE)** |
|---|---|---|
| Default (unknown diet composition) | | 6.5 |
| *Feeding forages of known quality with grain* | | |
| Low quality grass or legume forages including hay, silage and pasture (> 50% NDF; 25% ADF) with low grain); excludes small grain silage and corn silage | < 0.25 | 7.5 |
| Low quality grass or legume forages including hay, silage and pasture (> 50% NDF; 25% ADF) with low grain supplement | < 0.25 | 7.0 |
| Moderate forage quality (40-50% NDF; 20- 30% ADF) and low grain supplement | < 0.25 | 7.0 |
| Moderate forage quality (40-50% NDF; 20- 30% ADF) and high grain supplement | > 0.25 | 6.5 |
| High forage quality (including cereal silages, corn silage) and low grain supplement | < 0.25 | 6.5 |
| High forage quality (including cereal silages, corn silage) and high grain supplement | >0.25 | 6.0 |
| Situations in which adjustments apply to $Y_M$ values above* | | |
| 1. Use of monensin ionophores either as CRC bolus or in feed | | 10% reduction** |
| 2. Feeding fats* | | |
| Calcium salts of palm oil (or similar bypass fats) | | No reduction |
| Oilseeds, not to exceed 6% on dry matter basis. | | 5% reduction for every 1.0% added fat on DM basis |
| 3. Corn distillers dried grain with solubles (DDGS) fed, to a maximum of 20% on dry matter basis. | | 0.5% reduction for every 1.0% |

| | | |
|---|---|---|
| | | DDGS on DM basis |

* Feeding fats, DDGS and ionophores together are additive
** A 10% reduction in $Y_M$ = 7.0, for example, is calculated as 7.0 X 0.9 = 6.3.

**NOTE:** Dietary manipulation to reduce enteric methane production is an important strategy in whole farm reduction of greenhouse gas emission. Short-term effects of certain inhibitory compounds are well known. Because of microbial adaptation, the effect of dietary modifications over the long term is less certain. Efficacy of feeding an ionophore can be short-lived, producing a reduction in $Y_M$ that applies for only about 4 to 6 weeks. To capture the benefit of ionophores for reduced enteric emissions in the Dairy Protocol, the dairy farm nutritionist must design and document ionophore treatments to last no longer than 6 weeks, with at least 4 weeks between treatments. Other dietary manipulations have a sustained effect. This includes lipids and corn DDGS. To be effective, oilseeds must be crushed before feeding, and levels in the diet must not exceed the recommended levels of 4 to 6 per cent on a dry matter basis. Corn DDGS cannot exceed 20 per cent of dray matter of ration, and the higher protein content of the DDGS must be addressed in the ration formulation to prevent excess nitrogen excretion. The procedures to implement proper use of lipids and corn DDGS must be documented by the nutritionist.

### Greenhouse Gas Emissions from Feed Production

Emission factors applied in this protocol are expressed in $CO_2$ equivalents ($CO_2e$) and combine $N_2O$ and $CO_2$ emissions. $CH_4$ has been excluded because emissions of this gas are not considered to be significant in Canadian cropping systems.

- Nitrous oxide sources are from N-fertilizer application (chemical or organic), crop residues, leaching and volatilization. IPCC equations adapted for Canada by Rochette *et al.* (2008) were used.
- Carbon dioxide sources are from fossil fuel use for field work, electricity, crop drying and fertilizer and machinery supply. The F4E2 model was used (Dyer and Desjardins, 2003, 2005).

Feedstuffs for cattle are divided into 10 categories, each with its own emission factor. The 10 categories are presented below while emission factors are presented in **TABLE 2.4.5**:

- Four Grains:
  - Corn grains
  - Other small grains
  - Soybeans (and other legumes)
  - Canola meal and other protein supplements
- Four Forages:
  - Legume hay/silage
  - Non-legume hay/silage
  - Corn silage
  - Small grain silage
- Pasture
- "Other" – including DDGS – with estimates averaged

**Processed Feed**

Emissions arising from the production of feed can be calculated using specific emission factors for various regions and types of feed. Equation 11, below, is the basic equation and is used along with data found in **TABLE 2.4.5** to determine offsets from feed production.

$$E_{SSR9} = \sum_{G,F} FeedDM_{G,F} * FeedCO_2e_F \qquad [11]$$

Where:

**$E_{SSR9}$** = Greenhouse Gas emissions from feed production (excluding pasture), tonnes $CO_2e\ yr^{-1}$
**G** = Animal group
**F** = Feed type
**$FeedDM_{G,F}$** = Amount of feed of a specific type consumed by a specific animal group, tonnes DM $yr^{-1}$
**$FeedCO_2e_F$** = Greenhouse Gas emitted per tonne of feed, tonnes $CO_2e$ $tonne^{-1}$ feed DM

Feed $CO_2e$ were calculated for each province, combining both $N_2O$ and $CO_2$

The feed category "Others" refers to dried distillers grains with solubles (DDGS). Calculated emissions consider only DDGS from grain corn and wheat. The calculations is as follows: assuming that 1t corn produces 309kg DDGS and 1t wheat produces 295kg DDGS, the emission factor for these two crops shall be inflated by 3.24 (i.e. 1/0.309) for corn and 3.39 (i.e. 1/0.295) for wheat.

**TABLE 2.4.5 - Emission factors ($tCO_2e$ / tonne of feed) for different crop category**

| | Crop category | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| | ($tCO_2e$/t.feed) | | | | | | | | | |
| NF | n.a. | n.a. | n.a. | n.a. | 0.06 | 0.26 | n.a. | n.a. | | n.a. |
| PE | n.a. | 0.55 | 0.31 | n.a. | 0.07 | 0.21 | n.a. | 0.24 | | 1.73 |
| NS | 0.46 | 0.67 | n.a. | n.a. | 0.06 | 0.24 | 0.12 | 0.27 | | 1.69 |
| NB | n.a. | 0.65 | n.a. | n.a. | 0.05 | 0.23 | 0.1 | 0.27 | | 1.74 |
| PQ | 0.46 | 0.77 | 0.36 | 1.3 | 0.06 | 0.18 | 0.1 | 0.3 | | 1.85 |
| ON | 0.41 | 0.58 | 0.34 | 1.21 | 0.05 | 0.18 | 0.1 | 0.21 | | 1.52 |
| MB | 0.36 | 0.43 | 0.2 | 0.82 | 0.04 | 0.22 | 0.07 | 0.2 | | 1.21 |
| SK | n.a. | 0.29 | n.a. | 0.78 | 0.05 | 0.21 | n.a. | 0.14 | | 0.87 |
| AB | 0.29 | 0.35 | n.a. | 0.83 | 0.04 | 0.21 | 0.05 | 0.15 | See TABLE 2.4.6 | 1 |
| BC | n.a. | 0.48 | n.a. | 1.3 | 0.05 | 0.22 | 0.05 | 0.18 | | 1.49 |

| Legend | | | | | |
|---|---|---|---|---|---|
| | (1) Corn grains | (2) Other small grains | (3) Soybeans | (4) Canola | (5) Legume hay/silage |
| | (6) Non-legume hay/silage | (7) Corn silage | (8) Small grain silage | (9) Unimproved Pasture | (10) "Other" (DDGs – from corn and wheat) |

n.a.=not available(meaning that, according to the agricultural census, these specific crops are not cultivated in the province)

**Pasture Feed**

Practice change with respect to use of pasture is not included as a greenhouse gas reduction strategy in the Protocol. However, to accurately quantify reductions on dairy farms, the emissions associated with use of pasture must be quantified in both Baseline and Project.

For pasture, the ninth category, results are given per animal and per year because animal weight varies. Hence, emission factors are presented for an equivalent of 1000kg of live weight (LW) per year ($kgCO_2e./(tLW.yr)$). As an example, for a cow which weighs 600kg the emission factor must be multiplied by 0.6.

In this protocol pasture refers to "unimproved pasture". As a result, $N_2O$ emissions are only due to deposited manure. Direct $N_2O$ emissions from manure decomposition and indirect emissions such as volatilization and leaching are included, but $N_2O$ from N-chemical fertilizers and crop residues is excluded, as is $CO_2$ from fossil energy. Methane emissions from enteric fermentation and manure are not included for the following reasons:

1) Enteric fermentation emissions do not apply to crops;
2) $CH_4$ emissions from manure deposited on pasture are considered negligible.

Greenhouse Gas emissions from pasture feed can be calculated using Equation 12:

$$E_{SSR9,\,pstr} = \sum_{G} PstrCO_2e_G * LW_G * F_{pstr,G} * N_G \qquad \textbf{[12]}$$

Where:

$\mathbf{E_{SSR9,pstr}}$ = Greenhouse Gas emissions from pasture feed utilization, tonnes $CO_2e\ yr^{-1}$ **(TABLE 2.4.6)**
$\mathbf{G}$ = Animal group
$\mathbf{PstrCO_2e_G}$ = Greenhouse Gas emissions from unimproved pasture per tonne liveweight per year for a specific animal group, tonnes $CO_2e\ tonne^{-1}\ LW\ yr^{-1}$
$\mathbf{LW_G}$ = Average liveweight for a specific animal group, tonne
$\mathbf{F_{pstr,G}}$ = Fraction of annual dry matter intake obtained from pasture
$\mathbf{N_G}$ = Number of animals

**NOTE:** Use of pasture is a factor in quantification of the greenhouse gas emissions from dairy farms. Increased use of pasture can decrease the energy embedded in feed, resulting in decreased emission of $CO_2$ from feed production and processing. Decreased use of pasture can increase collection and storage of liquid manure, resulting in greater emission of methane from manure. However, uncertainty remains concerning the assessment of the quantity and quality of feed consumed by pastured cows, resulting in uncertainty concerning enteric emissions of methane. To conform to ISO 14064-2 principle of completeness, Protocol projects are required to use the Protocol quantification approach to account for greenhouse gas emissions associated

with use of pasture to account for potential increase of greenhouse gas emissions in the Project compared to the Baseline. But, to address the remaining uncertainty concerning greenhouse gas emission reductions, and to conform to the ISO 14064-2 principle of conservativeness, Protocol projects must demonstrate that any estimated decreases in greenhouse gas emissions associated with the increased use of pasture are ***not included*** in the calculation of offset credits.

**TABLE 2.4.6 - Emission Factors for Unimproved Pasture Feed Utilization by Different Animal Groups**

| | Dairy Cows | Heifers (>1yr) | Calves |
|---|---|---|---|
| | Tonnes $CO_2e$ $LW^{-1}$ $yr^{-1}$ | | |
| Atl Prov. | 1.90 | 1.34 | 1.16 |
| PQ | 1.90 | 1.34 | 1.16 |
| ON | 1.90 | 1.34 | 1.16 |
| MB | 1.87 | 1.32 | 1.15 |
| SK | 1.83 | 1.29 | 1.12 |
| AB | 1.80 | 1.27 | 1.10 |
| BC | 1.81 | 1.28 | 1.11 |

LW: Liveweight (tonnes)

### Feed Transportation

Practices and greenhouse gas emissions associated with the transportation of produced feed are not expected to change from baseline to project and, as a result, do not need to be quantified.

**TABLE 2.5** – Quantification Procedures

| ID number (Source/Sink) | Data type | Data variable | Data unit | Measured (m) calculated (c) estimated (e) | Recording Frequency | Proportion of data monitored | How will data be archived? (electronic paper) | For how long is archived data kept? | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Enteric Fermentation** | | | | | | | | | |
| Enteric Methane - 1 | Gross energy intake for a specific animal group | $GE_G$ | MJ head$^{-1}$ day$^{-1}$ | m (advanced) e (basic) | Daily (advanced) Monthly (simple) | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 2 | Percent of gross energy in feed converted to methane for a specific animal group | $Y_{mG}$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 3 | Number of animals in a specific animal group | $N_G$ | Head year$^{-1}$ | c | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 4 (Basic) | Net energy for maintenance | $NE_m$ | MJ head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 5 (Basic) | Maintenance energy coefficient | $Cf_i$ | MJ head$^{-1}$ kg$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 6 (Basic) | Average live weight of cows | LW | kg | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 7 (Basic) | Net energy for activity | $NE_a$ | MJ head$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | day $^{-1}$ | | | | | credit | |
| Enteric Methane – 8 (Basic) | Fraction of time spent on pasture | $F_{pstr}$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 9 (Basic) | Net energy for pregnancy | $NE_p$ | MJ head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 10 (Basic) | Fraction of animal group that are pregnant | $F_{pregp}$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 11 (Basic) | Net energy for lactation | $NE_l$ | MJ head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 12 (Basic) | Amount of milk produced | Milk | Kg head$^{-1}$ day$^{-1}$ | m | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 13 (Basic) | Fat content of milk | Fat | % by weight | m | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 14 (Basic) | Net energy for growth | $NE_g$ | MJ head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 15 (Basic) | Average live body weight for animals in group | BW | kg | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 16 (Basic) | Mature live body weight for an adult cow | MW | kg | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric | Average daily | WG | Kg day$^{-1}$ | e | Daily | 100% | Electronic | Minimum of two | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Methane – 17 (Basic) | weight gain | | | | | | | years after last issuance of carbon credit | |
| Enteric Methane – 18 (Basic) | Ratio of net energy available for maintenance to digestible energy consumed | REM | | c | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 19 (Basic) | Digestible energy expressed as a percentage of gross energy | DE | % of gross energy (GE) | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 20 (Basic) | Ratio of net energy available for growth to digestible energy consumed | REG | | c | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 21 (Advanced) | Dry matter intake for each ration ingredient (including edible oils, ionophores, etc.) | DMI | Kg $head^{-1}$ $day^{-1}$ | m | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Enteric Methane – 22 (Advanced) | Measure of quality of forage (NDF) | NDF | | m | Monthly | 100 | Electronic | Minimum of two years after last issuance of carbon credit | This data could be provided by nutritionist judgment for diet formulation . |
| **Manure Storage** | | | | | | | | | |
| Manure Storage – 1 (Basic) | Daily volatile solids excreted by a specific animal group | $VS_G$ | kg DM $head^{-1}$ $day^{-1}$ | m | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 2 | Number of animals in a | $N_G$ | Head $year^{-1}$ | m | Monthly | 100% | Electronic | Minimum of two years after last | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (Basic) | specific animal group | | | | | | | issuance of carbon credit | |
| Manure Storage – 3 (Basic) | Methane conversion factor | $MCF_S$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 4 (Basic) | Fraction of animal group G's manure handled by the defined manure management system | $MS_{S,G}$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 5 (Basic) | Daily volatile solids excreted per day on a dry matter basis | VS | kg head$^{-1}$ day$^{-1}$ | e | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 6 (Basic) | Gross energy intake | GE | MJ head$^{-1}$ day$^{-1}$ | e | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 7 (Basic) | Digestible energy | DE | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 8 (Advanced) | Volatile solids added to manure storage unit during month for all animal groups contributing to unit | $VS_{prod,m}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 9 (Advanced) | Volatile solids in the storage unit at the end of the previous month available to be | $VS_{avail,m-1}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Manure Storage – 10 (Advanced) | Fraction of available volatile solids consumed during month | f | | c | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 11 (Advanced) | Volatile solids available to be decomposed at end of current month | $VS_{avail,m}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 12 (Advanced) | Volatile solids available to be decomposed at end of previous month | $VS_{avail,m-1}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 13 (Advanced) | Volatile solids added to manure storage unit during month | $VS_{prod,m}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 14 (Advanced) | Volatile solids consumed during month | $VS_{consumed}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 15 (Advanced) | Volatile solids stabilized into non-available forms | $VS_{stabilized}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 16 (Advanced) | Volatile solids removed from manure storage during month | $VS_{removed}$ | tonnes | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Manure Storage – 17 (Advanced) | Average monthly temperature | $T_2$ | °C | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| **$N_2O$ Emissions** | | | | | | | | | |
| $N_2O$ Emissions - 1 | Feed N intake for a specific animal | $FeedN_G$ | Kg N $head^{-1}$ $day^{-1}$ | m | Daily | 100% | Electronic | Minimum of two years after last | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | group | | | | | | | issuance of carbon credit | |
| $N_2O$ Emissions - 2 | Dry matter intake | DMI | Kg head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 3 | Crude protein content of diet | CP | % of DMI | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 4 | Nitrogen retained in milk for a specific animal group | $MilkN_G$ | Kg N head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| N2O Emissions – 5 | Daily milk production | Milk | Kg head$^{-1}$ day$^{-1}$ | m | Daily | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 6 | Protein content of milk | Milk protein | % on weight basis | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 7 | Nitrogen retained in liveweight gain for a specific animal group | LWgain $N_G$ | Kg N head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 8 | Daily liveweight gain | LWgain | Kg head$^{-1}$ day$^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 9 | Number of animals in a specific animal group | $N_G$ | Head year$^{-1}$ | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 10 | $N_2O$ emitted per kgof N excreted for a specific animal group | $E_{N2O,G}$ | kg $N_2O$ kg$^{-1}$ excreted N | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ Emissions - 11 | Fraction of excreted N handled by manure management system for a specific animal group | $F_{G,S}$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| $N_2O$ Emissions - 12 | N2O emitted per kg of N excreted in a specific manure management system | $E_{N2O,S}$ | Kg $N_2O$ kg excreted $N^{-1}$ | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| **Feed** | | | | | | | | | |
| Processed Feed - 1 | Amount of feed of a specific type consumed by a specific animal group | $FeedDM_{G,F}$ | tonnes DM $yr^{-1}$ | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Processed Feed - 2 | Greenhouse Gas emitted per tonne of feed | $FeedCO_2e_F$ | Tonne $CO_2e$ $tonne^{-1}$ feed DM | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Pasture Feed – 1 | Greenhouse Gas emissions from unimproved pasture per tonne liveweight per year for a specific animal group | $PstrCO_2e_G$ | tonnes $CO_2e$ $tonne^{-1}$ LW $yr^{-1}$ | c | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pasture Feed – 2 | Average liveweight for a specific animal group | $LW_G$ | tonne | e | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |
| Pasture Feed - 3 | Fraction of annual dry matter intake obtained from pasture | $F_{pstr,G}$ | % | e | Monthly | 100% | Electronic | Minimum of two years after last Pasture Feed - 4issuance of carbon credit | |
| Pasture Feed - 4 | Number of animals in a specific group | $N_G$ | Head $year^{-1}$ | m | Monthly | 100% | Electronic | Minimum of two years after last issuance of carbon credit | |

### 2.5.2 Contingent Data Approaches

Not applicable in this Protocol.

## 2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data must be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily verification will be to conduct for the project.

### 2.6.1 Record Keeping

Alberta requires that Project Developers maintain appropriate supporting information for the project, including all raw data for the project for a period of 7 years **after** the end of the project credit period. Where the Project Developer is different from the person implementing the activity, as in the case of an aggregated project, the individual farmer and the aggregator, must both maintain sufficient records to support the Offset Project. The project developer (farmer and aggregator) must keep the information listed below and disclose all information to the verifier and/or government auditor upon request.

**Record Keeping Requirements:**

- Raw baseline period energy, feed, milk production, livestock, and manure management data, independent variable data, and static factors within the measurement boundary
- A record of all adjustments made to raw baseline data with justifications
- All analysis of baseline data used to create mathematical model(s)
- All data and analysis used to support estimates and factors used for quantification
- Expected end of life date of equipment removed or renovated under the project
- Common practices relating to possible greenhouse gas reduction scenarios discussed in this protocol (such as manure management practices)
- Metering equipment specifications (model number, serial number, manufacturer's calibration procedures)

- A record of changes in static factors along with all calculations for non-routine adjustments
- All calculations of greenhouse gas emissions/reductions and emission factors
- Measurement equipment maintenance activity logs
- Measurement equipment calibration records
- Initial and annual verification records and audit results

In order to support the third party verification and the potential supplemental government audit, the project developer must put in place a system that meets the following criteria:

- All records must be kept in areas that are easily located;
- All records must be legible, dated and revised as needed;
- All records must be maintained in an orderly manner;
- All documents must be retained for 7 years after the project crediting period;
- Electronic and paper documentation are both satisfactory; and
- Copies of records should be stored in two locations to prevent loss of data.

Note: Attestations will not be considered sufficient proof that an activity took place and will not to meet verification requirements.

### 2.6.2 Quality Assurance/Quality Control

Quality Assurance/Quality Control can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Ensuring that the changes to operational procedures (including feed intake, manure management, etc.) continue to function as planned and achieve greenhouse gas reductions
b Ensuring that the measurement and calculation system and greenhouse gas reduction reporting remains in place and accurate
c Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data
d Performing recalculations of quantification procedures to reduce the possibility of mathematical errors
e Storing the data in its raw form so it can be retrieved for verification
f Protecting records of data and documentation by keeping both a hard and soft copy of all documents
g Recording and explaining any adjustment made to raw data in the associated report and files.
h A contingency plan for potential data loss.

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